THE DIFFRACTION OF MOLECULAR BEAMS AT CRYSTAL SURFACES. METHODS OF DETECTION

BY
ROBERT JEROME THORN
B.S., Alma College, 1938

AN ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN
CHEMISTRY IN THE GRADUATE SCHOOL OF
THE UNIVERSITY OF ILLINOIS, 1942

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METHODS OF DETECTION

Introduction

The most direct method of studying a surface is to observe the diffraction of a molecular beam from it. This method is analogous to the study of crystal structure by an x-ray or electron beam. In molecular beam studies one is confronted with a very difficult problem in technique: namely, the problem of detection. For, whereas x-rays and electron beams are detected readily because of their high energies, beams of molecules, because of their small thermal energies, are without effect upon photographic plate or fluorescent screen. Consequently an extensive study of surfaces and surface layers awaits the development of more powerful methods of detection of molecular beams.

The requirements of a method of detection are (1) it should be quantitative; (2) it should record the complete diffraction pattern; and (3) it should permit the use of different molecular species in the beam. Of these (1) is the most important and (3) the least. As yet no method has been developed which satisfies all three. Quantitative methods[1] developed up to the present time require a point by point exploration for the various orders of diffraction. Present methods which give a complete picture of the diffraction pattern are not quantitative. It is desirable, therefore, that the present methods of detection be improved to fulfill the first two conditions cited.

Proposed Methods

1. The "Positive Ion Grid" Detector. The principle of this proposed method is the same as that of the Kingdon cage[2] in which the negative space charge about the surface of an electron emitter is neutralized by positive ions. The

first method differs from the second, however, in that the electrons would be emitted in a spotwise manner — that is, only where the diffracted beam strikes the surface. If these electrons should be released in sufficient numbers, the pattern of the diffracted beam on the emitter surface could be transferred to a fluorescent screen. Since the intensity of fluorescence is proportional to the number of electrons striking the screen and since in turn the number of electrons released per second would be proportional to the number of beam molecules striking the emitter per second, the method could be made quantitative. The "positive ion grid" detector then would fulfill all three of the above cited essentials of a detector.

2. The Work Function Detector.

(a) Oxygen on Oxide Coated Cathodes. Koller[3] studied the effect of various gases on the electron emission from oxide coated cathodes. It was found that oxygen at a pressure of 5×10^{-3} mm. decreased the emission by a factor of 10^{-3}. From this it follows that the oxide coated cathode is a very sensitive detector for molecular oxygen beams. Furthermore, provided the emission can be decreased in a spotwise manner the complete diffraction pattern can be transferred by the electrons to a fluorescent screen.

Experimental

1. The "Positive Ion Grid" Detector. In order to explore the possibility of formation of a "positive ion grid" at the surface of an electron emitter as mentioned above, an apparatus designed after the tubes employed by Johnson and Shockley[4] in the study of the surfaces of tungsten filaments was constructed. The only essential difference was that the present apparatus had an arrangement for directing a jet of gas at the emitter. Evidence that a gaseous jet directed at an electron emitter releases electrons only where the atoms strike the emitting area was obtaind with helium, hydrogen, and oxygen. The effect was observed with the emitter at room temperature and also at higher temperatures. It was also observed under conditions of varying field strength

at the surface of the emitter. The mechanism for the release of these electrons is thought to be through positive ion bombardment and not through the formation of a "positive ion grid." When the jet was replaced by a helium beam the effect was not observed.

2. Oxygen on Oxide Coated Cathode. The emission current of an oxide coated cathode was measured both in the absence and in the presence of an oxygen beam. It was found that a beam intensity of 5×10^{16} molecules per square centimeter per second decreased the emission of an activated oxide coated cathode at 500°C. by 30 per cent when only about 5 per cent of the emitter surface area was struck by the oxygen beam.

Conclusions

No satisfactory explanation for the failure of a molecular beam to enhance the electron emission of a surface can be given. However, in view of the positive results obtained with a molecular jet directed at a thoriated tungsten filament, and at a tantalum strip, a method of detecting molecular beams based upon the "positive ion grid" justifies further investigation. A restricted method for beam detection which employs the change of the work function of an oxide coated cathode appears to be the most hopeful method proposed.

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VITA

The author was born December 1, 1914 in Constantine, Michigan. He attended the public schools in Constantine and Three Rivers, Michigan. He was graduated from Three Rivers High School in June, 1933. In September, 1934, he entered Alma College where he served as undergraduate assistant in chemistry from 1935 to 1938. He was graduated with a B.S. degree, summa cum laude, in June, 1938. In September, 1938 he entered the graduate school at the University of Illinois. During the time of attendance he served as graduate assistant in physical chemistry. He is a member of Sigma Xi and Phi Lambda Upsilon.

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